PHYSICO-CHEMICAL AND BACTERIOLOGICAL CHARACTERISTICS AND QUALITY ASSESSMENT OF GROUNDWATER FROM SHALLOW AQUIFER IN ABAKALIKI TOWN, SOUTHEASTERN NIGERIA

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ABSTRACT

The physico-chemical and bacteriological characteristics of fifteen (15) water samples collected from fifteen hand-dug wells constructed in shallow aquifer (depth, 3-4m) in Abakaliki Town were determined, and the results used to assess the quality of the water for drinking purpose, using Nigerian Industrial Standards (NIS) and World Health Organization (WHO) standards as guidelines. Results of the study indicate that the groundwater satisfy the quality standards for most of the chemical parameters with the exception of pH and hardness in some wells (pH below 6.5-8.5 in 12 out of the 15 well; and hardness above 100mg/l in 6 out of the 15 wells). On the basis of physical and bacteriological parameters, none of the water well samples satisfies the quality standards of taste and turbidity (objectionable and turbidity units greater than 5.0 NTU, respectively); 6 out of the 15 water well samples do not satisfy the colour quality standards (above 3.0 colour units); and 10 out of the 15 water well samples do not satisfy the faecal coliform quality standards (above zero (>0) per 100ml). Groundwater from shallow aquifer in Abakaliki town is therefore generally polluted in terms of physical, chemical and bacteriological characteristics (high turbidity, slightly acidic and contains high faecal coliform). The causes of the pollution may be partly geologic (aquifer is weathered shale of the ASU River Group geologic formation) and partly anthropogenic (seepage from septic tanks/pit toilets and solid waste sites, and poor well construction/maintenance practices). In order to improve the quality of groundwater from Abakaliki Town (study area), the hand-dug wells should not be sited in the vicinity of the septic tanks/pit toilets and measures should be taken to prevent inflows of surface runoff/overland flow into newly constructed/existing hand-dug wells. Water from the wells should also be adequately treated to reduce turbidity, acidity and coliform bacteria contents.

Keywords: Physico-chemical, bacteriological, groundwater, hand-dug well, aquifer and water quality.

1.0   Introduction

Groundwater is water that is found in the zone of saturation and occurring naturally in voids. This water is held in the subsurface under the hydrostatic pressure below the water table. The quantity, physical, chemical and biological characteristics of groundwater determine its usefulness for industry, agriculture or domestic purposes. Water derived from groundwater and other sources may not necessarily be pure since it contains dissolved inorganic and organic substances, living organisms (viruses, bacteria, etc).

Groundwater has long been regarded as the pure form of water compared to surface water, because of purification of the former in the soil column through anaerobic decomposition, filtration and ion exchange. This is the reason for preference consumption of groundwater in rural and semi-urban areas all over the world (WHO, 1984). It is estimated that approximately one third of the world's population uses groundwater for drinking purposes (Domenico and Schwartz, 1988).

Any water intended for drinking purposes should be free from toxic substances and microorganisms that are of health significance (Ezeigbo, 1989). More than 88% of the global diarrhoea diseases are water-borne infections caused by drinking unsafe and dirty water (Davis and Cornwell, 1998). It is also estimated that 1.1 billion people in developing countries have no access to clean water, and 2.4 billion people have no form of sanitation services. Consequently, 250 million people are exposed to water-borne diseases resulting in 10-20 million deaths every year. The chemical composition of groundwater and the water types found in an environment are determined greatly by the composition of precipitation, local geology, types of minerals found in the environment through which recharge and groundwater flows, anthropogenic activities such as mining and waste disposal as well as climate and topography (Egboka et al, 1998). Suitability of groundwater for domestic use is determined by it geochemistry (Domenico, 1992).

Within aquifers, groundwater is hosted by minerals which influence its hydro-geochemistry and ultimate quality. The quality of water is determined by its chemical composition and therefore its ultimate usability and its assessment and the parameters examined depend on the envisaged usage. In some cases, water quality is far more important than its availability. On account of the wide variety of water, hydro-geochemical characteristics and the consequent different standards of portability, it is impossible to set rigid standards of chemical quality. The evolution of groundwater is explained by the order of encounter (Freeze and Cherry, 1979). This theory states that the order in which groundwater encounters strata of different mineralogical composition can exert an important control on the final water chemistry.

2.0 Study Area Description
2.1   Location of study area

The study area covers Abakaliki and its environs. It extends laterally into Ekaruinyimagu, Agbaja and Nkwagu all in Ebonyi State (Fig.1). Geographically, the area is located between latitude $6^0 15^I$N and $6^0 17^I$N and longitude $8^0 05^I$E and $8^0 10^I$E covering a total area of about 1,328sq/km. The area stretches down towards Ogoja Road area off Amachi-Obugha down to Okwerike. Major villages within the study area include Abakaliki, Azuiyiokwu and Ugboloke. It has major and minor network of roads connecting each other in the map.

Fig. 1
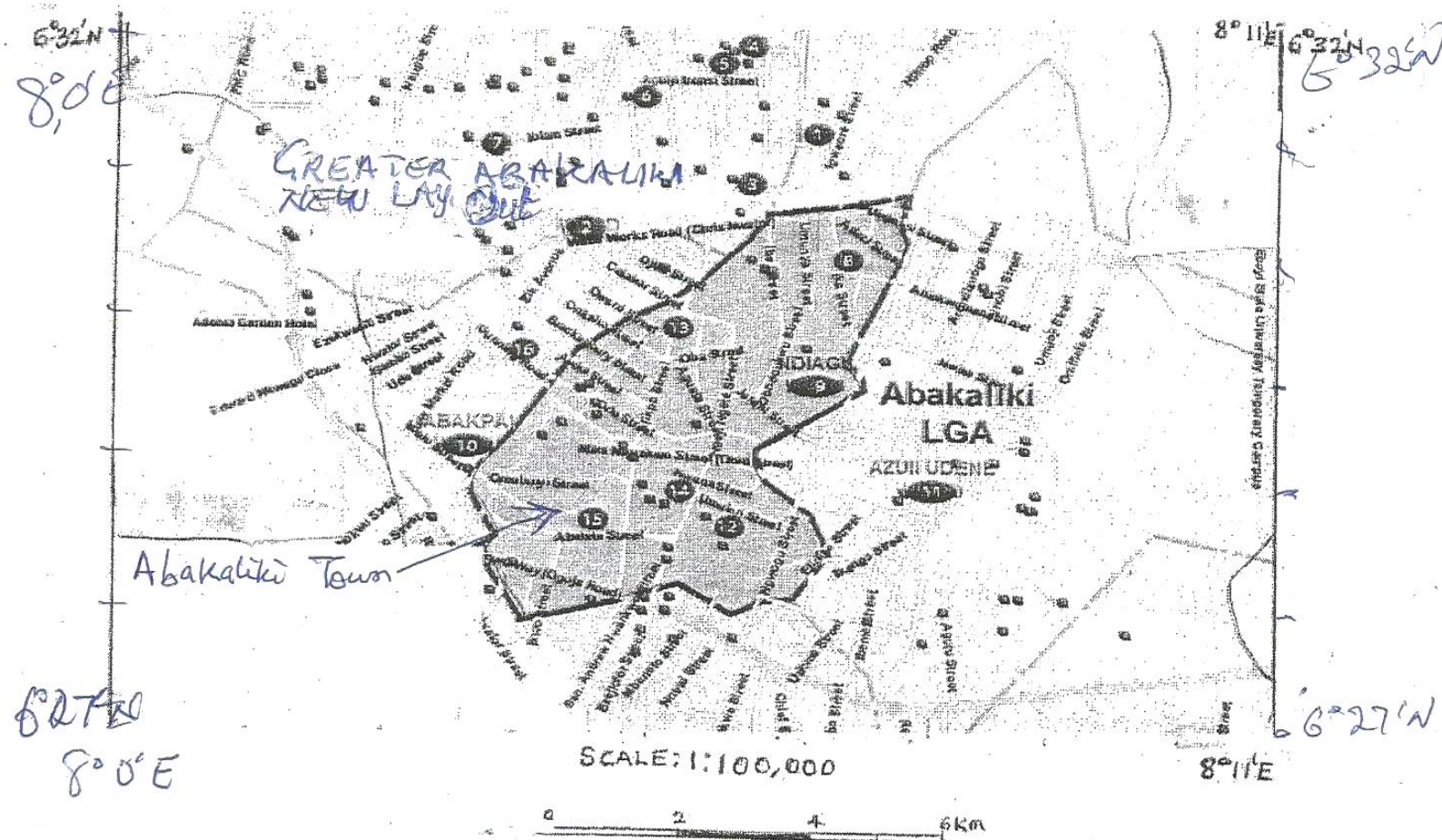
Location map of the study area.

2.2   Geology of the study area

The study area is underlain by the shales of Asu River Group. The Asu River Group is the oldest sedimentary rock in southern Nigerian (Reymet, 1965). The shales are exposed variously in the Abakaliki area where they are often referred to as the Abakaliki Shale. The Asu River Group of mid Albian age in the Southeastern Nigeria. The Abakaliki shale are poorly bedded, occasionally sandy and consists of Splintery metamorphosed mudstones. Lenses of sandstone and sandy limestone are highly jointed and fractured. The geologic history of Abakaliki basin is characterized by compressional tectonic stresses. The associated stresses caused metamorphism and fracturing of older marine and volcanic rocks. Primary porosity is low due to geologic conditions. The low primary porosity suggests very poor groundwater transmission and storage capabilities; however, the development of secondary porosity by fracturing and faulting has led to increase in the bulk permeability of the fractured shale. The area is predominantly underlain by shale, sandstone, siltstones, sandy shale and limestone. Abakaliki town is also characterised by occurrence of pyroclastic rocks which has been extensively weathered to give rise to shallow aquifer in the area (Uzuakpunwa, 1974; Orajaka and Umenwaliri, 1989).
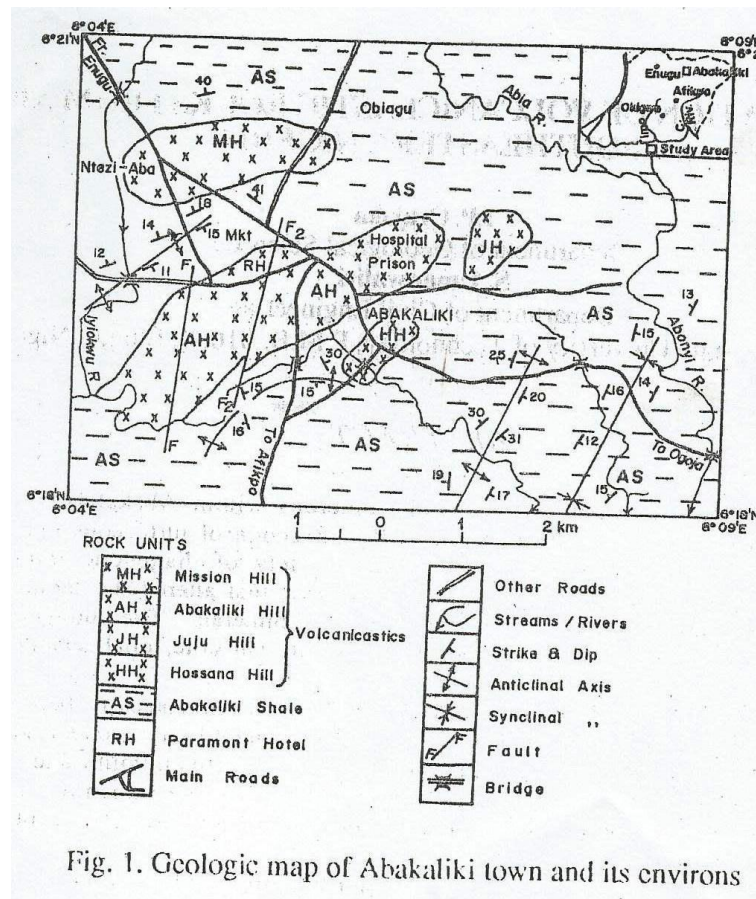
Fig. 1. Geologic map of Abakaliki town and its environs

3.0 Materials and Methods

3.1   Sample collection

Samples for physical analysis were collected and pH measured by use of pH meter 350 model and other parameters measured with turbidity meter (Nephlometric /606c) Hatch model, odorized kit, colorimetric comparator kit and measuring thermometer. Samples for chemical analysis were collected by the use of polysetheryne free test containers, beakers, round

bottom flask, conical flask, fitted lids bottle and measuring cells. The collected samples at the point of collection were stabilized with sodium thiosulphate. Water samples were collected from groundwater and shallow hand-dug well for hydrogeochemical analysis.

A total of fifteen samples were collected randomly from eight locations and analysed. Nine samples were collected from shallow boreholes and hand-dug wells while five were collected from manual drilled sources.

The required volumes usually within the recommending standard of 10ml to 125ml were pumped into the various measuring containers and stabilized for laboratory analysis. For on-site test for temperature, 125ml of volume were collected into the wide-mouth glass bottles and then the thermometer was dipped into the sample and allowed for at least three minutes before taking the readings. At each location, observations on the physical aspects of water quality such as colour, taste and odour were done, colour concentrations (test) were analysed in the field by the use of measuring cells known as colorimetric comparator while that of odour was by the use of odorized kit. Samples were collected at each location mainly for heavy metals load concentrations analysis. Samples for heavy metals test were filtered and stabilized with two (2) to three (3) drops of dilute sodium thiosulfate at the point of collection.

Table 1 shows description of sampling locations (Hand-dug wells)

Table 1: Location of water wells sampled

LOCATION NO.	LOCATION NAME	LATITUDE	LONGITUDE
Location 1	Igwuore Street	$6^{o}, 31.1'N$	$8^{o}, 7.2'E$
Location 2	Water works road	$6^{o}, 30.25'N$	$8^{o}, 5.5'E$
Location 3	Udemezue Street 1	$6^{o}, 30.7'N$	$8^{o}, 6.7'E$
Location 4	Udemezue Street 2 (near Catholic Church)	$6^{o}, 31.1'N$	$8^{o}, 6.7'E$
Location 5	Aguiyi Ironsi Street 1	$6^{o}, 31.7'N$	$8^{o}, 6.5'E$
Location 6	Aguiyi Ironsi Street 2 (New lay out)	$6^{0}, 31.5'N$	$8^{o}, 5.8'E$
Location 7	Ibiam Street	$6^{o}, 31.05'N$	$8^{o}, 4.8'E$
Location 8	Ike Street	$6^{o}, 31.05'N$	$8^{0o}, 7.4'E$
Location 9	Obodoukwu Street	$6^{o}, 28.8'N$	$8^{o}, 7.25'E$
Location 10	Izuelu Street	$6^{o}, 28.25'N$	$8^{o}, 4.6'E$
Location 11	Jereni Street	$6^{o}, 27.95'N$	$8^{o}, 8.1'E$
Location 12	Umuleri street	$6^{o}, 27.6'N$	$8^{o}, 6,6'E$
Location 13	Afikpo street	$6^{o}, 29.4'N$	$8^{o}, 6.15'E$
Location 14	Nwana Street	$6^{o}, 27.95'N$	$8^{o}, 6.2'E$
Location 15	Abatete street	$6^{o}, 27.65'E$	$8^{o}, 5.5'E$

3.2 Laboratory Measurements

3.2.1 Physico-chemical parameters

Physical and chemical parameters of water samples were tested by using multi parameter water testing kit method (APHA, 1989). Various physicochemical parameters: pH, Temperature, Colour, Odour, Taste, Turbidity, Copper, Fluoride, Iron, Manganese,

Magnesium, Calcium, Sodium, Chloride, Lead, Cyanide, Aluminium, Selenium, Vinyl Chloride, Bicarbonate, Sulphate, Zinc, Potassium, Phosphate and Nitrate. Total dissolved solid (TDS), Electrical Conductivity (EC), Total hardness (TH), Total Dissolves solvent.

3.2.2 Bacteriological parameters

The bacteriological examination of water samples were assessed by MPN test and total plate count method (Batterman et al, 2000). Total plate count can indicate the total count of bacteria in water, purification treatment efficiency, and the polluted degree of pipes. Too high total bacterial the water has already been polluted by microbes (Batterman et al, 2000). Therefore, total plate count is an important parameter indicating whether the drinking water has been polluted by microbes, and can be used essentially to assess the disinfection effect. Drinking water with a total plate count of 100-500 Cfu/ml will harm the health of human beings (APHA, 1998).

4.0   Results and Discussion

4.1   Physical parameters

Table 2 shows the results of physicochemical analysis of the water wells studied. Figures 3 and 4 is the graphical illustration of the results.

Physical parameters include pH (H+ concentration), Turbidity, Electrical Conductivity, Colour etc. The pH of groundwater in the study area ranges from 5.9 to 7.25. This indicates that the water is slightly neutral in most places. The pH fall within the permissible standard for the WHO guideline for drinking water which is between 6.5 to 9.5, SON of 6.5 to 8.5 and NIS standard of 6.5 to 8.5 as shown in table 1. The turbidity of the groundwater sample in the area ranges between 15.81 to 19.8 mg/l which is unacceptable with the WHO standard (2011). Turbidity exceeding 5mg/l is not good for domestic use. Therefore, majority of the available water sources in the area are considered turbid. The electrical conductivity of groundwater samples ranges between 615 to 805 µs/m which is far below WHO standard of 1200 µs/m and SON standard of 1000 µs/m. This conductivity does not exceed the WHO standard.

Table 2: Summary of physico-chemical characteristics of groundwater from Abakaliki town

Parameter	Location 1 (Ighuror	Location 2 (Water work	Location 3 (Udemezer e Street 1)	Location 4 (Udemezer	Location 5 (Aguiyi	Location 6 (Aguiyi	Location 7 (Ihioma Street)	Location 8 (Ike Street)	Location 9 Obodoukw	Location 10 Izuelu	Location 11 Aguiyi	Location 12	Location 13 (Afikpo	Location 14 (Nwere Street)	Location 15 (Abatete	NIS Standard	WHO Standard
Taste	Objectio nable	Objectio nable	Objectio nable	Objectio nable	Objectio nable	Objectio nable	Objectio nable	Objectio nable	Objectio nable	Objectio nable	Objectio nable	Objectio nable	Objectio nable	Objectio nable	Objectio nable	Unobject ionable	Unobject ionable
Odour	Objectio nable	Unobject ionable	Unobject ionable	Objectio nable	Objectio nable	Objectio nable	Unobject ionable	Objectio nable	Objectio nable	Objectio nable	Objectio nable	Objectio nable	Objectio nable	Unobject ionable	Objectio nable	Unobject ionable	Unobject ionable
Colour (TCU)	4.13	3.87	2.91	3.57	4.89	4.65	2.88	2.83	4.26	4.19	3.35	3.85	2.89	2.85	3.78	3.00	5.00
Temperature (°C)	28	28	28	27	27	27.5	28	27.5	28	27.6	28	27.5	28	28	28	Ambient	Ambient
Turbidify (NTU)	18.63	16.81	17.2	18.28	19.81	19.81	17.11	18.11	19.81	16.50	17.02	19.63	17.81	16.19	17.10	5.00	5.00
Chloride (mg/l)	74.7	48.9	65.8	50	62.2	58.9	10.4	47.5	64.5	8.50	44.7	55.6	115.4	65.8	58.2	100.00	250.00
Copper (mg/l)	Nil	Nil	Nil	Nil	Trace	Nil	0.41	Nil	Trace	0.08	Nil	Nil	Trace	Nil	Nil	1.00	2.00
Fluoride (mg/l)	Nil	Nil	0.4	Nil	Nil	Nil	Trace	Nil	Nil	Nil	Trace	Nil	Nil	Nil	Nil	1.00	1.5.0
Iron (mg/l)	0.14	Trace	0.05	0.15	0.02	0.21	Trace	Trace	0.17	Nil	0.12	Trace	0.16	0.17	0.11	0.3	0.3
Manganese (mg/l)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Trace	Nil	Nil	Nil	Nil	0.5	0.40

| Nitrote (mg/l)	4.18	1.85	3.02	3.0	5.0	5.18	2.85	2.06	3.85	5.12	2.81	2.28	2.50	2.75	2.02	10.00	50
Calcium (mg/l)	75.2	26.7	50.7	45.1	70.5	45.5	28.2	30.6	67.2	69.2	38.5	21.5	24.7	62.5	43.5	75.00	200
Total dissolved solids (mg/l)	364.3	297.6	330.95	350.3	375	385.3	305.5	295.4	365.5	351.30	307.2	285	358.2	345.4	298.4	500.00	500
PH	6.78	6.67	6.73	6.24	6.56	5.0	7.25	6.12	6.4	5.94	6.21	6.35	6.95	6.01	6.24	6.5-8.5	6.5-9.5
Acidness (mg/l)	198.0	75.2	166.6	85.2	176.7	202.5	76.8	84.2	205.1	204.1	65.8	62.5	71.27	178.2	84.4	500.00	500.00
Conductivity (cm/ohm)	792	647	719.5	615	789	805	688	627	810	782	643.3	651	615.00	723	630	1000	1200
Lead (mg/l)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Trace	Nil	Nil	Nil	Trace	.01	.01
Sulphate (mg/l)	60.4	58.8	59.6	55.5	74.8	70.4	68.8	64.8	62.4	64.5	61.5	62.3	62.8	59.1	60.2	100.00	500
Cyanide (mg/l)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0.01	0.05
Total Alkality (mg/l)	23.9	22.3	23.1	21.3	24.4	16.15	24.7	24.5	27.5	25.7	25.5	24.5	24.5	26.5	24.3	100.00	100.00
Zinc (mg/l)	0.86	Nil	Nil	0.16	Nil	0.94	Nil	Nil	0.78	0.75	0.14	0.75	Nil	0.65	0.34	5.0	3.0
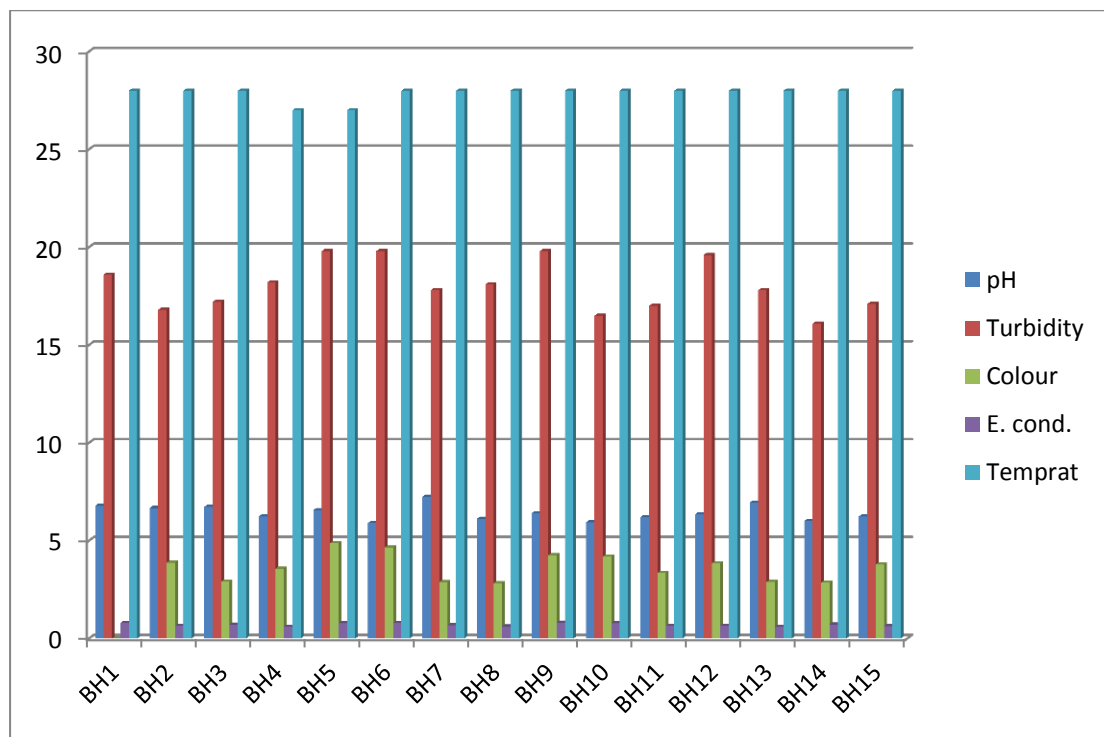
Figure 3: Result of Some Physical Parameters in Water Samples Analysed

4.2   Chemical parameters

Studies of the various water samples showed that total dissolved solid (TDS) have the highest value of 385 mg/l in borehole 6 and a minimum value at well 12 with 285 mg/l which is in accordance with the Nigerian Industrial standard (NIS). The results indicated that the sampled water are safe for domestic use and are in compliance with WHO (2011) standard for drinking water. The concentration of Chlorine (Cl) in all the borehole analyses are below the WHO standard of 100mg/l and were within the WHO standard for drinking water except borehole 13 where it recorded 115mg/I. The concentration of Iron (Fe) in the study area are below the Nigerian Industrial Standard (NIS) of 0.3mg/l and these results indicate that most of the areas studied has concentration levels that are in accordance with WHO (2011) permissible standard for drinking water. Calcium are within the NIS and WHO standard of 75 mg/i. Total Alkalinity levels recorded in the borehole analysed are moderately low (16mg/l - 27mg/l). Potassium concentration from borehole 1, 2, 4, 5, 7, 9, and l5 which are above the WHO Standard of 10mg/l and this implies that water sources in these areas have higher concentration that are far above WHO (2011) standard. Finally, the hardness of water in HDW 1,3,5,6,9,10 and 14 which are (198, 166, 179, 202, 205, 204 and 178) mg/l respectively are far above the SON, NIS and WHO standard of 100mg/l.
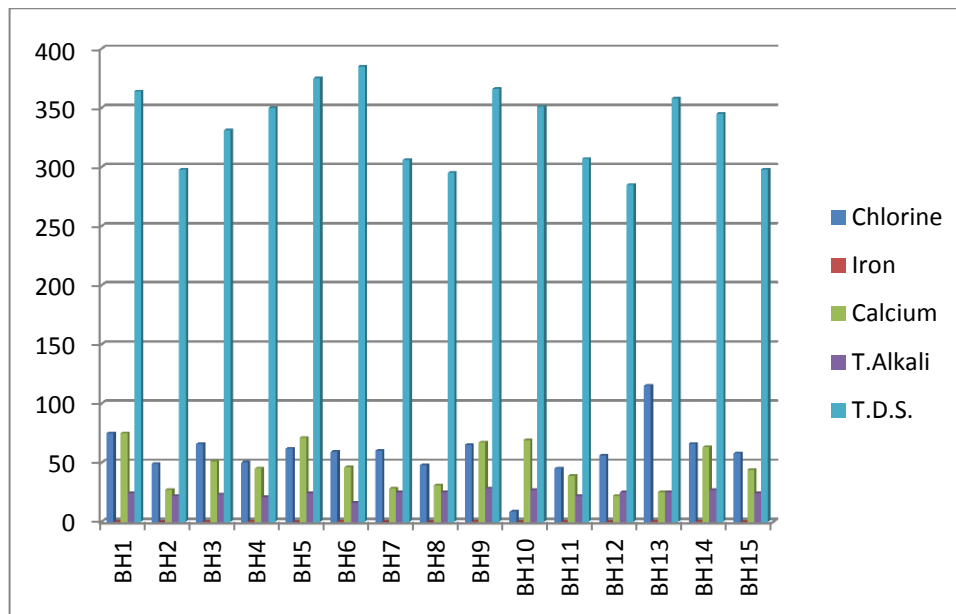
Figure 4: Result of Some Chemical Parameters in Water Samples Analysed

4.3 Bacteriological parameters

Table 3: Faecal coliform, counts of the groundwater samples

SAMPLE	FAECAL COLIFORM COUNT cfu/100ml
Sample 1	0
Sample 2	84
Sample 3	0
Sample 4	125
Sample 5	0
Sample 6	25
Sample 7	0
Sample 8	0
Sample 9	87
Sample 10	0
Sample 11	77
Sample 12	0
Sample 13	20
Sample 14	175
Sample 15	25

Tables 4 show the WHO and NAFDAC standard guidelines for drinking water, while table 3 show the health impacts of physico-chemical constituents in groundwater.

Table 4: Approved Physiochemical Standards for Portable Water

S/N	Parameter	NIS max. Allowed standard	WHO standard
1	Colour	3.0 TCU	5.0 TCU
2	Odour	Unobjectable	Unobjectable
3	Taste	Unobjectable	Unobjectable
4	pH at 20°C	6.5-8.5	6.5-9.5
5	Turbidity	5 NTU	5 NTU
6	Conductivity	1000(as/cm)	1200(as/cm)
7	Total Solid	500mg/l	500mg/l
8	Total Alkalinity	100mg/l	100mg/l
9	Phenolphthalein Alkalinity	100mg/l	100mg/l
10	Chlorine	100mg/l	250mg/
11	Fluoride	1.0mg/l	1.5mg/l
12	Copper	1.0mg/l	2.0mg/l
13	Iron	0.3mg/l	3.0mg/l
14	Nitrate	10mg/l	50mg/l
15	Nitrate	0.02mg/l	0.3mg/l
16	Manganese	2.0mg/l	0.4mg/l
17	Magnesium	20mg/l	20mg/l
18	Zinc	5.0mg/l	3.0mg/l
19	Selenium	0.01mg/l	0.01mg/l
20	Silver	-	-
21	Cyanide	0.01mg/l	0.07mg/l
22	Sulphate	100mg/l	500mg/l
23	Calcium	75mg/l	NS
24	Aluminium	0.5mg/l	0.2mg/l
25	Potassium	10.0mg/l	NS
26	Lead	0.01mg/l	0.01mg/l
27	Chromium	0.05mg/l	0.05mg/l
28	Cadmium	0.03mg/l	0.03mg/l
29	Arsenic	0.01mg/l	0.01mg/l
30	Barium	0.05mg/l	0.05mg/l
31	Mercury	0.01mg/l	0.01mg/l
32	Antimony	NS	0.02mg/l
33	Tin	-	1.2mg/l
34	Nichel	-	0.02mg/l
35	Total Hardness(CaCO3)	100mg/l	500mg/l
36	Vinyl Chloride	0.0mg/l	0.003mg/l

Table 5: Health impact of physic-chemical constituents in groundwater (NIS, 2005)

S/N	Parameters	Health impact
1	Aluminum (Al)	Potential Neuro-degenerative disorder
2	Arsenic (As)	Cancer
3	Barium (Br)	Hypertension
4	Cadmium (Cd)	Toxic to Kidney
5	Chloride (Cl)	None
6	Chromium (Cr)	Cancer
7	Conductivity	None
8	Copper (Cu)	Gastrointestinal disorder
9	Cyanide (Cn)	Very toxin to the thyroid and nervous system
10	Fluoride (F)	Flourosis skeletal tissues(bones and teeth)
11	Hardness (CaCO$_3$)	None
12	Hydrogen Sulphide (H$_2$S)	None
13	Iron (Fe)	None
14	Lead (Pb)	Cancer and affect mental development in infant
15	Magnesium (Mg)	Consumer acceptability
16	Manganese (Mn)	Neurological disorder
17	Mercury (Hg)	Affect kidney and central nervous system
18	Nickel (Ni)	Possible carcinogenic
19	Nitrate (NO$_3$)	Cyanosis and asphyxia
20	Nitrite (NO$_2$)	Cyanosis and asphyxia
21	pH	None
22	Sodium (Na)	None
23	Sulphate (SO$_4$)	None
24	Total dissolved solid (TDS)	None
25	Zinc (Zn)	None

Table 6: Microbiological Permitted Level (NIS, 2005)

S/N	Parameter	Unit	Maximum Permitted levels
1	Total coliform count	CFU 100/ml	10
2	Faecal coliform e.g E.coli (thermotolerant coliform)	CFU 100/ml	0

5.0   Conclusions and Recommendations

5.1   Conclusions

Microbial analysis reveals the presence of coliform and E.coli in two hand-dug well (HDW7 and I3) and one borehole well (BH20). These contaminations are perhaps traceable to have originated from human activities (Septic tanks, latrines, dumpsites) and have affected the quality of groundwater in the study area.

The information given about Abakaliki and environs is to assess the portability of the subsurface water and the findings are as follow:

1. The physicochemical analysis shows that some parameters fall below (WHO, 2011) acceptable limit for drinking water. Magnesium and Calcium are well below (WHO, 2011) standard. Only potassium concentration from borehole 1, 2, 4, 5, 7, 9, and l5 are above the WHO Standard of 10mg/l and this implies that water sources in these areas have higher concentration that are far above WHO (2011) standard.

2. The heavy metal analysis shows little abnormal concentration of lead in the wells. The hardness of water in well 1,3,5,6,9,10 and 14 which are (198, 166, 179, 202, 205, 204, 178) mg/l respectively are far above the SON, NIS and WHO standard of 100 mg/l though they are slightly above the permissible limit. Arsenic was not found at all in any of the sample. The heavy metal distribution is averagely acceptable in the area.

3. Except for three sample sites (Well 7, Well 13, and well 2), the area is free of bacteriological count.

4. There is low level of calcium and magnesium, with the above conclusions, the groundwater of Abakaliki and environ are generally soft. Both calcium and magnesium are essential to human health, inadequate intake of either nutrient can impair health.

5. The pH of the area varies in that (WHO, 2011) standard. The pH is averagely acceptable, it can be deduced that most of the contamination are from dumpsites, leaking septic tank and pit latrines located in the area

5.2   Recommendations

Having assessed the quality of the water samples from hand dug wells in the area, the following recommendations are put forward to enhance the quality of drinking water:

1. Habitants of the area should be advised to embrace good hygiene habits and keep sanitary environment clean. Building modern toilets for good use.

2. Based on findings of this research project, we recommend that people who make use of the ground water in the selected area should not only boil water before drinking, but also keep the surroundings clean to reduce chance of ground water contamination.

3. Efforts should be intensified to avoid siting of wells close to possible sources of contamination such as septic tanks, latrines, waste dumps, mining and quarry sites.

4. Distribution pipes and channels should be periodically checked to identify possible sources of contamination like broken parts and leakages.

5. Plastic pipes should be used instead of iron pipes to prevent contamination due to ferric ions and astringent taste usually associated with water samples collected from such pipes.

6. There should be regular analysis of quality and indicator parameters in our drinking water sources to determine their portability.

7. There should be surveillance in order to keep a careful watch to ensure safety of drinking water supplies. This would involve sanitary inspection and quality analysis and sanitary inspection has the objectives of identifying potential risks of contamination and sources of pollution.

8. Health education is required to explain the relationship between health, water, sanitation and hygiene. Community involvement is essential to protect water supplies from pollution and to perform the basic surveillance and maintenance of water and sanitation

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